Ozone Depletion: Causes, Potential Effects and Remedies

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The ozone layer functions as a protective screen, filtering out most of the sun's harmful ultraviolet (UV) rays. This protective layer is located in the stratosphere between 15km and 35km above the earth's surface. Ozone is actually a form of oxygen. In the lower atmosphere, oxygen atoms commonly bond with each other in pairs. This molecule, abbreviated as 0_2, *is the form of oxygen we need to breathe. Ozone is a more unstable and uncommon molecule made up of 3 oxygen atoms and is abbreviated* 0_3.

In addition to the stratospheric ozone layer, ozone also is found in the layer of the atmosphere closest to Earth, known as the troposphere. While the ozone layer in the stratosphere far above our heads protects us from UV radiation, ozone in the troposphere is harmful to breathe and damages crops and trees. Tropospheric ozone is formed by the reaction of sunlight with substances such as car exhaust and industrial chemicals and is often referred to as photochemical smog. Ozone in the troposphere provides some protection from UV rays, but its dangers far outweigh its benefits.

What is damaging the ozone layer?

The ozone layer is being attacked by man-made chemical compounds containing chlorine and bromine. The most common of these are chlorofluorocarbons (CFCs) and bromofluorocarbons (halons). Because of their stable chemical structure, these compounds don't break down in the lower atmosphere. They take 5 to 10 years to reach the stratosphere, where they are broken down by intense UV radiation [1]. This breakdown releases atoms of chlorine (from CFCs) or bromine (from halons) that react with and destroy ozone. Each of these atoms is able to react repeatedly and destroy as many as 100,000 ozone molecules [2].

The evidence

Since 1985, scientists have been studying the ozone "hole" that forms every year over the South Pole during the Antarctic spring. Within this hole ozone levels are depleted by as much as 50% to 60% [2]. The size and duration of the hole continue to increase, opening earlier and closing later each year, exposing an area larger than the United States to unusually high levels of UV radiation. In the last several years this depletion has extended to include southern Chile.

In 1991 a team of United Nations (UN) scientists found that not only is the ozone layer thinning over middle latitudes in both the northern and southern hemispheres, but that depletion is now also occurring during the summer. Up to that point, depletion had been recorded only during the colder winter months. Depletion over the United States now averages 3.5% in summer and reaches 5.5% in the winter, exceeding 5% into early June[3].

In February 1992, NASA released data from its Second Airborne Arctic Stratospheric Expedition showing extremely high levels of ozone-depleting chlorine monoxide in the atmosphere over most of the northern United States, Canada, northern Europe, and Asia. Depending on weather conditions, this chlorine could cause temporary ozone loss of as much as 30% to 40% over these heavily populated areas during any given winter in the next several years[4]. The same press release reported ozone loss of up to 10% over tropical latitudes, including much of Hawaii, probably related to sulfate droplets in the volcanic plume from the 1991 eruption of Mt. Pinatubo in the Philippines. Scientists hypothesize that these sulfate droplets catalyze the destruction of ozone by chlorine[5].

At present, predictions for future ozone-depletion over the remainder of the decade vary. At the conservative end, some scientists predict another 3% loss by the year 2000. Dr. Joe Farman, a British scientist who was one of the discoverers of the Antarctic ozone hole, projects roughly a 20% depletion over the United Kingdom and northern Europe [6]. This projection has been echoed by Dr Sherwood Rowland, one of the scientists who, in 1974, first suggested that CFCs had the potential to damage the ozone layer. Between these high and low extremes, the United Nations Environmental Programme based its studies of the impact on the environment the result of ozone depletion as a sustained average of 10%[7].

Banning the CFCs

The destruction of ozone by CFCs was first hypothesized in the early 1970s; this led to public outcry, a ban on their use in aerosols in the United States and a temporary decrease in their emissions. However, despite knowledge of their destructive capability, the usefulness of CFCs and halons in other areas led to huge increases in production through the mid-1980s. By the late 1980s, CFC and halon use was considerably higher than it had been prior to the aerosol ban in 1978[8].

CFCs are used widely as refrigerants in air conditioners, refrigerators, freezers and heat pumps; as blowing agents for

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some foam plastics; as solvents in the cleaning of metals and the manufacturing of electronics. Halons are used as agents in fire extinguishers in both large stationary systems designed to protect electronic equipment and in portable ones.

Other ozone-depleting chemicals include carbon tetrachloride, used primarily as a solvent; methyl chloroform (1,1,1-trichloroethane), used as a metal cleaner; and in various products such as spot removers, insecticides and shoe polish sprays. Methyl bromide has recently been found to be released by fungicides.

The United States is the world's largest producer and consumer of CFCs and halons, accounting for close to 30% of world production and use[8]. Since 1990, United States CFC production has been cut in half, but still has a long way to go. Because of their proven threat to our health and environment, we need to stop using these chemicals, and we can do this without lowering our standard of living (for infomation on how to reduce the use of these chemicals see the section entitled "Meanwhile what can we do?").

The alternatives

Many replacement chemicals now are available; others are being tested. Generally they are far less destructive to ozone, while being almost as efficient as those currently in use. Substitutes such as HFC-134a (used as a replacement refrigerant for CFC-12) and butane (used as a blowing agent) have no damaging effect on ozone; however, they still contribute to the greenhouse-warming effect. Many companies that used CFCs as solvents have successfully switched to alternatives, such as citrus extracts or even soap and warm water.

Refrigeration companies are developing appliances using helium, butane, and hydrogen as coolant gases. Other alternatives, such as hydrochlorofluorocarbons (HCFCs), are considered by many to be interim substitutes because their ozone-depleting potential is far lower than that of CFCs. Eventually these will need to be phased out as well, as some HCFCs may be more destructive to ozone than previously thought[9].

Can the ozone layer repair itself?

Ozone is constantly being both created and destroyed in the stratosphere. The average life of an ozone molecule is relatively short and until recently ozone was being created at least as fast as it was being destroyed. Unfortunately, the chlorine and bromine compounds we have released into the atmosphere have altered this balance, and they are destroying ozone faster than it can be created. After emissions of these chemicals cease, the ozone layer will eventually repair itself. However, recent estimates indicate that even if we stop all CFC emissions today, depletion will continue to worsen for at least a decade before any repair can begin. For the same reason, the Antarctic ozone hole is estimated to not fully repair itself until the late 21st century[3].

The effect of ozone depletion

Life as we know it on Earth developed under the protective shield of the ozone layer and has been sustained by this protection for nearly a billion years. Significant depletion of this shield will be harmful to both humans and other living things on which we are dependent. Dangers from elevated levels of UV radiation include:

On human health:

- **Increased instances of skin cancer:** According to the United Nations Environmental Program (UNEP) *Environmental Effects of Ozone Depletion 1991 Update*, every 1% thinning of the ozone layer will result in approximately a 2.3% to 2.6% increase in non-melanoma skin cancer. This report, based on data from ongoing research by NASA and the international scientific community, predicted that a sustained 10% decrease in ozone will be associated with a 26% increase in non-melanoma skin cancer. All things being equal, this would result in an increase in excess of 300,000 cases per year world wide [7].
- **Increased instances of cataracts, the leading cause of blindness in the U.S.:** The same UNEP report also predicted that, all things being equal, a sustained 10% decrease in ozone depletion will lead to between 1.6 and 1.75 million additional cataract cases a year worldwide[7]. UV also is associated with age-related nearsightedness and solar retinopathy, or eye burn, which can cause temporary blindness.
- **Weakening of the immune system:** Recent evidence indicates that while people with fair skin are most likely to suffer the brunt of increased skin cancers resulting from ozone-depletion, people of all skin types are at equal risk of the immunosuppressive effects of elevated UV radiation levels. Recent research cited in the 1991 UNEP report indicates that exposure to UV also can activate the HIV virus [7].
- **Premature wrinkling, toughening and aging of the skin.**

On crops and other land plants:

- **Reduced crop yields and stunted growth of natural vegetation:** Plant groups sensitive to increases in UV radiation include beans, melons, peas, and cabbage. Soybeans, the third most important food crop in the U.S., have been found to be particularly sensitive to elevated UV levels. According to the 1991 UNBP report, a 25% reduction in ozone could cause a decrease in soybean production of up to 20% [7].

On marine life:

- **Disruption of the marine food chain and further reduction of already shrinking fisheries:** Fish larvae and phytoplankton living near the ocean surface are harmed by exposure to increased levels of UV radiation. Phytoplankton account for 75% of marine plant mass and form the base of the marine food chain. Additionally, these organisms are important in the production of oxygen. Recent research in the Antarctic found a 6% to 12% reduction in primary productivity by marine phytoplankton, attributed to elevated UV levels under the Antarctic ozone "hole"[9].

Aside from the studies cited above, there has been relatively little research on the impact of ozone depletion on terrestrial and marine ecosystems. While human beings can offset the effect of higher UV levels by adopting behavioral changes, this is not as easy for some other organisms to do. Increased

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UV radiation is also only one of many pressures, along with loss of habitat, changing climate, and introduced species, placed on organisms and ecosystems by human-induced global change. In the face of uncertainty over the compound effect of these pressures, we must take whatever steps we can to mininimize depletion of the ozone layer.

What we can do

Depletion of the ozone layer is a global problem. It stands to affect all people in all parts of the world. Solving the ozone problem requires action and cooperation from world organizations, national, state and local governments, industry, and individuals.

The role of government

The U.S. is one of approximately 70 nations that signed the Montreal Protocol on Substances that Deplete the Ozone Layer. This 1987 UN treaty called for a 50% reduction from 1986 levels in CFC production and a freeze on the production of halons. In London in 1990 these provisions were strengthened to require a complete phase-out of CFCs and halons by 2000, with the elimination of methyl chloroform and carbon tetrachloride by 2005 and 2000 respectively. The 1990 revisions of the U.S. Clean Air Act call for a similar phase-out schedule, while also providing some regulation in areas not covered by the Protocol[2].

Since 1990, these phase-out dates have shifted in response to information provided by ongoing research. In 1992 the U.S. government followed the lead of many European countries by announcing an acceleration of the phase-out schedule for CFCs and carbon tetrachloride. Production of these chemicals now will cease by December 1995. Halon production will be eliminated in 1994. These same phase-out dates were adopted later in the year by the other parties of the Montreal Protocol, while the European Community upped the ante by agreeing to stop producing CFCs by January 1995[10].

These are all important steps and should be applauded. In the coming years similar policies that are responsive to new research findings will need to be developed to address other environmental threats as well. However, we should remember that international agreements and federal regulation are only part of the solution. Until CFCs, halons and other ozone depleters are finally phased out there are other steps that can be taken to prevent unnecessary emissions of these chemicals. As was mentioned earlier, many companies are finding ozone-safe substitutes and switching over to them in advance of the dates required by law. Several state govermnents also have taken action. Hawaii was the first state in the nation to mandate recovery and recycling of CFCs used in car air-conditioners and to ban over-the-counter sales of the chemicals. Vermont, Oregon, Florida, Maine and Minnesota followed suit.

Meanwhile what can we do?

The 1990s have been called the decade of individual responsibility. We as individuals can make a difference with the products we use and the choices we make. When the threat to ozone posed by CFCs in aerosol sprays was first reported in the 1970s, American consumers simply stopped buying aerosols once they learned of the danger these sprays posed to the ozone layer. This action prevented large amounts of CFCs from being released into the atmosphere and led to a government ban on CFC use in aerosol products. Here are steps that individual consumers can take today to protect the ozone layer:

1) Leaking car air-conditioners have traditionally been the largest source of CFC emissions in the United States. Both federal and state laws require service stations to recover and recycle CFCs when air-conditioners are repaired, but there has been little enforcement of these measures. Therefore:
   - Make sure your service station recycles CFCs before you have your air-conditioner repaired.
   - If you are buying a new car, consider a model without an air-conditioner or one using new non-depleting refrigerants.
2) Avoid foam containers and packaging such as foam popcorn unless they indicate that they were not made with CFCs or HCFCs. Not only do some of these contain ozone-depleting chemicals, but they are also a problem in disposal of waste. As of February 1989, most polystyrene manufacturers stopped using the most destructive CFCs, but some of the replacements, especially HCFC-22, have been found to be more damaging than previously thought.
3) Immediately repair any leaks in your refrigerator. If you are discarding a refrigerator, make sure the CFCs are recycled before it is scrapped. If you are buying a refrigerator, consider new CFC-free models.
4) Avoid purchasing halon fire extinguishers. These usually can be identified by the yellow canister. Traditional dry chemical or carbon dioxide models will work in most cases. The sale of most portable halon fire extinguishers will be prohibited in Hawaii beginning in July 1993. Call your local fire department for information; if you already own a halon extinguisher, store it until halon recycling is available.
5) Consider alternatives to air-conditioning in your home. If you are building a home, look into passive cooling designs. For an existing home, consider the following options:
   - Insulate to keep heat out.
   - Install a cooling system using fans.
6) Check all products before purchase to avoid ozone-depleting chemicals. These chemicals include: CFC-11, CFC-12, CFC-113, CFC-114, CFC-115, (The abbreviation CFC will sometimes be replaced by R for "refrigerant", i.e. R-11, R-12, R-113, etc.); Halon-1211, Halon-1301, Halon-2402, 1,1,1-trichloroethane (methyl chloroform), and carbon tetrachloride are also to be avoided.
7) Write to your federal, state and local government representatives and inform them of your concern about ozone depletion.

Global problems such as ozone depletion can seem huge, abstract, and impersonal, but just as we each stand to be affected by these problems, we can each make a difference. Talk about this and other global change issues with your family, friends, and colleagues, and follow the steps listed above that you as an individual can take to reduce ozone depletion.

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